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EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSIONS CHARACTERISTIC OF DEDICATED CNG ENGINE

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ABSTRACT

An emission from public transportation is a major concern today. The immediate need is to reduce the emissions and improve the efficiency and performance of these vehicles. This is not possible with the convention engines as they are designed for low compression ratio (CR) and for specific fuels only. To achieve this with less cost, the only option available is dedicated CNG engine in which higher CR can be used as compared to conventional engines. An experimental study was conducted on this engine by changing CR to 12:1 by modifying base Gasoline engine with CR 9:1 by changing the piston shape and clearance volume. Comparative study of performance i.e., Brake power (BP), Brake specific fuel consumptions (BSFC), Torque and Brake thermal efficiency (BTE) and emissions has been done with dedicated CNG engine and base engine with LPG, CNG and gasoline fuels. From this study, it is observed that dedicated CNG engine is giving 20.5% higher BTE, 19.3% more BP, 17% better BSFC,11.7%low exhaust gas temperature,68.8%,35.7% and 176.7%less HC+NOx, CO and CO_2emissions respectively as compared to baseline CNG engine. It is also observed that the power recovered is slightly in this engine.

KEYWORDS: Dedicated CNG Engine, Compression Ratio, Brake Power, Brake Thermal Efficiency & Emissions

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Original Article

1. INTRODUCTION

Fuel shortage and air pollution control are a major concern for research on fuel economy and reduction of exhaust emissions, which is the main study of engine development. Alternate fuel engine development is more important in engine research as compared to crude oil fuel engine which has limited reservoirs worldwide. Compared to conventional gasoline and diesel fuels, alternative fuels are cleaner. Introduction of alternative fuel has become essential to solve the problems of fuel shortage and to reduce the exhaust emissions. Natural gas is one of the best alternative fuel to traditional engines due to availability of abundant resources and its cleaner combustion characteristics. In taxies and public transportation, natural gas is widely used all over the world by replacing of spark ignition and compression ignition engine fuels. The high-octane number characteristic of the gas permits the engine to go for high compression ratio, leading to high thermal efficiency [1]. Also, from the previous studies, it has been observed that natural gas fuels give low emissions of HC and CO when compared to gasoline engines [2, 3]. However, Natural gas has low laminar flame speed due to high activation energy. This drawback can be overcome by increasing the turbulence in the combustion chamber (CC) by changing the shape of the combustion chamber [4-6]. Natural gas has low density fuel due to this the engine power is decreased as it occupies more volume of fuel in the air-fuel mixture; this drawback can be overcome by increasing the CR in natural gas engine [7-9].

Selection of compression ratio (CR) is the most important factor for CNG engines due to its high anti-knock property. Thermal efficiency is directly proportional to CR, increases power also with high CR. However,

increasing CR also leads to high NOx emissions, which is particularly at full load conditions. It is important to optimize CR to increase thermal efficiency without much change on NOx emissions. A lot of research has already been done on CR optimization. Kim et al. [10] conducted experimental study on the performance and emissions of the four-stroke engine by using two CRs in modified dual fuel which are gasoline and natural gas engine. They observed that, although engine performance was not much affected by CRs, exhaust HC, NOx and CO emissions were affected by CRs. HC and NOx emissions increased with increasing CR, and CO emissions were decreased with increasing CRs. Yamin et al. [11] studied numerically with different CRs which were obtained by changing the stroke length on four-stroke engine. They found that power increased with high CR. Chaiyot et al. [12] conducted experimental study on the performance and the emission characteristics of four-stroke dedicated CNG engine with different CRs by changing the piston shapes. They observed that by increasing the CR, engine power output also increased. NOx emissions increased with increasing CR up to certain CR after that NOx emissions decreased with increasing CR. HC emissions also increased with increasing CR, and CO emissions decreased with increasing CR. Das et al. [13] conducted experimental study on a four-stroke modified natural gas engine with different CRs. They observed that, an increase in CR led to enhancement of engine turbulence resulting in burning of lean mixture without cyclic fluctuations. The engine had given best performance at 15.4 CR with multi-port injection and maximum brake torque (MBT) timing. Also, at this CR, the engine had higher thermal efficiency and low HC and CO_2 emissions. Caton [14] studied numerically on the effect of CR on NOx emissions in four-stroke engine by using thermodynamic analysis. They found that, by increasing CR, NOx concentration increased up to certain CR and after that it decreased. Takagaki et al [15] conducted experiment on four-stroke engine to measure NOx emissions by changing the CR. They investigated that NOx emissions increased continuously on increasing the CR on fixed spark timing. But, on MBT timing, NOx emissions increased and after that decreased by increasing the CR.

Research has been done already on the performance and emissions of the engine by changing the CR from low to high for obtaining optimum CR, in which engine performance emissions were optimum. In this experimental study, the objective is development of dedicated CNG engine with an optimum CR i.e. 12:1 and to compare the performance and the emission results with that of a base engine i.e. with CR is 9:1 using different fuels i.e. natural gas, petrol and LPG in order to optimize dedicated CNG engine combustion chamber shape and CR.

2. EXPERIMENTAL SET-UP

The experimental setup consists of an engine dynamometer (Eddy current type). Different temperature and pressure sensors as mounted on engine. The oxygen sensor was used to check the lambda value of the fuel air mixture. The setup was used for the test of Greaves engine with Modified piston and Regular piston. The engine used which specifications are shown in the table 1 for this study has been a Greaves 510 Cubic centimeter (CC). The experimental set-up with details is shown in figure 1 and Engine is shown in figure 2. The set up consists of CNG cylinder along with its kit connected to intake manifold. The engine crank shaft is connected to Eddy current dynamometer.

Table1: Engine Specifications

Type	Two Valve, Four stroke
Bore	85 mm
Stroke	90 mm
Compression ratio	12
Maximum Power	11.9 HP @ 3000 rpm
IVO : 16 CAD bTDC	EVO : 40 CAD bBDC
IVC : 40 CAD aBDC	EVC : 16 CAD aTDC

Figure 1: Experimental Setup of the Engine Mounted on Bed and Coupled with Dynamometer.

In this application, engine is tested on itself (that is, out of the vehicle), with the dynamometer typically connected directly to the engine drive shaft at the flywheel. The test cell controller manipulates throttle position and other engine inputs. In this case, the dynamometer has its own controller, which communicates with the cell controller through a serial connection.

The use of a chassis dynamometer allows the assessment of "real world" emissions. This allows a better assessment of the benefits of new fuels and vehicle technologies and is essential to assessing the performance of heavy hybrid trucks, cars and buses. Vehicle testing is more complex than engine testing and is not as standardized.

3. RESULTS AND DISCUSSIONS

Figure 2, shows Comparison of Thermal efficiency with 12 CR dedicated CNG engine with bowl shape piston and 9 CR Flat Piston Engine at various engine speeds. From the figure 2, it has been observed clearly that thermal efficiency is more with 12 CR Dedicated CNG engine as compared to 9 CR CNG engine. Thermal efficiency is high in 12 CR dedicated engine, because of same fuel consumption when compared with 9 CR CNG engine. So, for the same fuel consumption dedicated CNG engine is giving more power and torque this leads to increase of thermal efficiency in this engine as compared to 9 CR CNG engine. Thermal efficiency more means Fuel conversion efficiency is more, this means faster combustion is possible in 12 CR dedicated CNG engine when compared with 9 CR CNG engine.

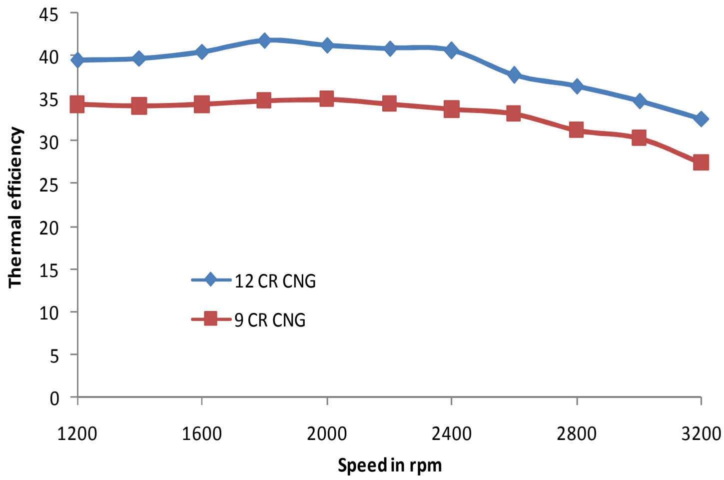

Figure 2: Variation of Thermal Efficiency with different Engines and Engine Speeds.

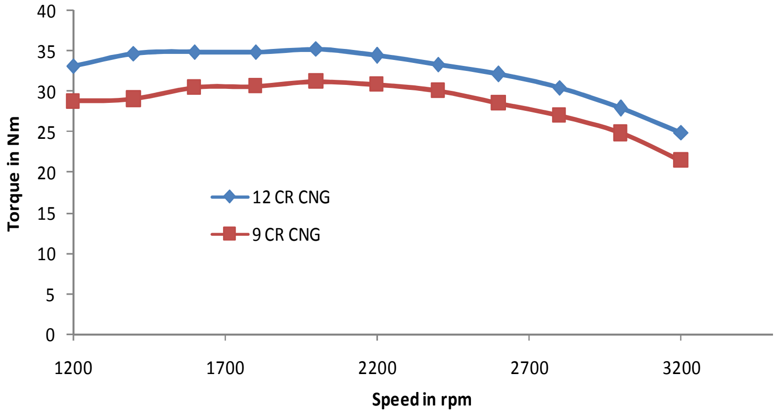

Figure 3: Variation of Brake Torque with different Engines and Engine Speeds.

Figure 3 shows comparison of Brake Torque with 12 CR dedicated CNG engine with bowl shaped piston and 9 CR CNG engine with a flat piston at various engine speeds. From the Figure 3, it was observed clearly that torque increased with 12 CR Dedicated CNG engine when compared to 9 CR CNG engine. In 12 CR engine due to compact combustion chamber and bowl-shaped piston, which enhances cylinder turbulence and leads to faster combustion? Faster combustion chamber always gives good performance because fuel conversion efficiency is more in this engine. Due to this effect, Torque of the 12 CR dedicated CNG engine is more.

Figure 4, shows comparison of Brake Power with 12 CR dedicated CNG engine with bowl shape piston and 9 CR CNG engine with flat piston. From the figure 3, it has been observed clearly that brake power is increased with 12 CR Dedicated CNG engine as compared to 9 CR CNG engine. In 12 CR engine faster combustion is generated because of compact combustion chamber with bowl shaped piston which will create more cylinder turbulence, so fuel conversion efficiency is more and also power of the engine is more.

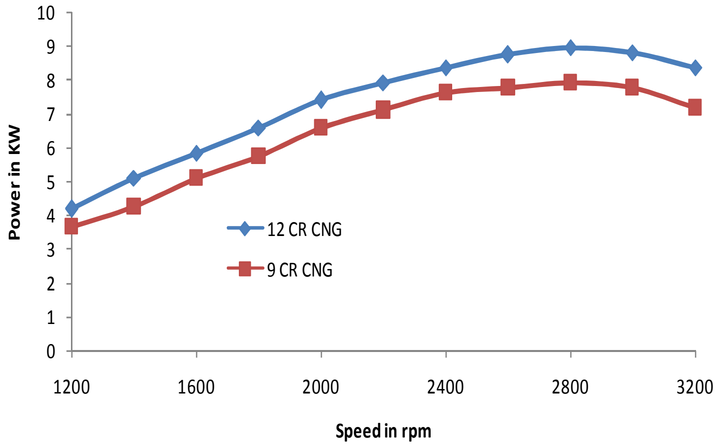

Figure 4: Variation of Brake Power with different Engines and Engine Speeds.

Figure 5, shows Comparison of BSFC with 12 CR dedicated CNG engine with bowl shaped piston and 9 CR CNG engine with flat piston with different engine speeds. From the Figure 5, it was observed clearly that BSFC values are decreased with 12 CR dedicated CNG engine as compared with 9 CR CNG engine. In 12 CR engine, faster combustion is generated due to compact combustion chamber and bowl-shaped piston. Because of this piston cavity higher turbulence is

generated in cylinder combustion space, this higher turbulence leads to faster flame propagation then better heat release rate that gives good bsfc.12 CR engine gives more power by using almost same fuel consumption, that is why BSFC is low in 12 CR dedicated CNG engine compared to 9 CR CNG engine.

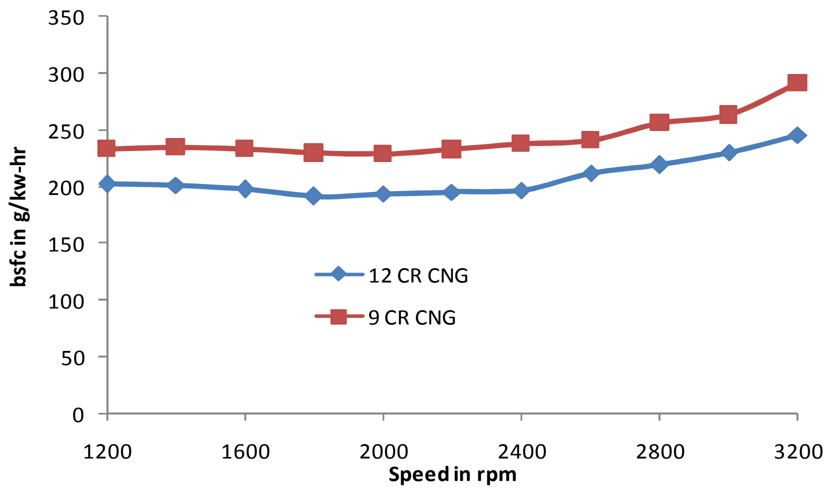

Figure 5: Variation of BSFC with different Engines and Engine Speeds.

Figure 6, shows comparison of exhaust gas temperature (EGT) with 12 CR dedicated CNG engine with bowl shaped piston and 9 CR CNG Engine with flat piston with different engine speeds. From the Figure 6, it has been observed clearly that exhaust gas temperature is less in 12 CR Dedicated CNG engine as compared to 9 CR CNG engine. This shows, Combustion Chamber is faster in 12 CR Dedicated CNG engine, expansion of combustion products is more as compared to 9 CR CNG engine. Faster Combustion Chamber gives less exhaust gas temperature as compared to slower Combustion Chamber, because most of the fuel gets burned before the opening of exhaust valve. By increasing CR from 9 to 12, combustion chamber goes to compact, and this leads to faster combustion of air and fuel.

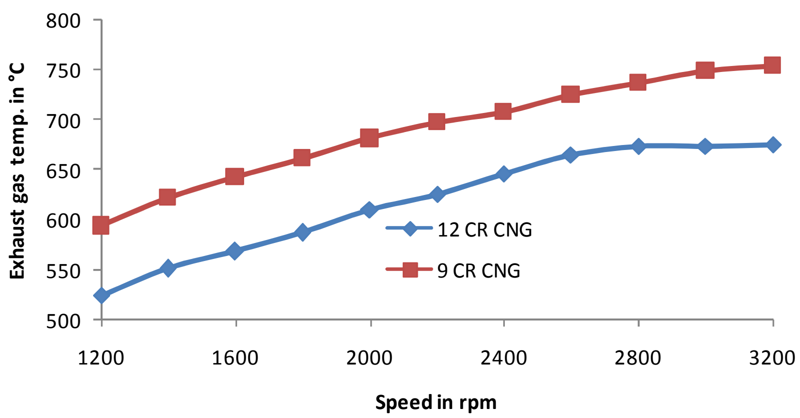

Figure 6: Variation of EGT with different Engines and Engine Speeds.

Table 2: Comparison of Emissions with different CR

Type of Engine	HC	NOx	HC+NOx in g/km	HC+NOx as per BS II Limits(g/km)	CO in g/km	CO as per BS II Limits in g/km	Results	CO2 in g/km
9 CR Engine	1.69	1.06	1.57	1.67	1.33	1.88	BS II Passed	100.4
12 CR Engine	1.38	0.52	0.93	1.67	0.98	1.88	BS II Passed	36.28

Table 2, shows comparison of emissions of 12 CR dedicated CNG engine with flat bowl piston and 9 CR CNG engine with flat piston. From the table 1, it was observed that emissions were decreased in 12 CR dedicated CNG engine as compared to 9 CR CNG engine. Mainly NOx has been decreased drastically because of lower exhaust gas temperature and retardation of ignition timing. Generally, ignition timing advance is required in engine operating with CNG mode as compared to Petrol and LPG modes, but in dedicated CNG engine retardation of ignition timing is almost equal to Petrol mode base engine. In dedicated CNG engine due to faster burning of mixture, less time is required to complete the combustion that is why ignition timing is retarded in dedicated CNG engine.

4. CONCLUSIONS

Based on experimental results of dedicated CNG engine, the following conclusions can be drawn:

- Dedicated CNG engine has 20.5% more thermal efficiency and 19.3% more Torque and power as compared to 9 CR CNG engine at 2400 rpm and 1400 rpm, respectively.
- Dedicated CNG engine has 17% less BSFC and 11.7% less exhaust gas temperature as compared to 9 CR CNG engine at 2400 rpm 1600 rpm, respectively.
- Dedicated CNG engine has 68.8% less $HC+NO_X$ emissions, 35.7% less CO emission and 176.7% less CO_2 emission as compared to 9 CR CNG engine.

From this study, it is observed that dedicated CNG is better option for SI engine in termsof performance and emissions.

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